Guidance on VOC Substitution and Reduction for Activities Covered by the VOC Solvents Emissions Directive (Directive 1999/13/EC)

Guidance 18:

Rubber conversion

European Commission - DG Environment

Contract ENV/C.4/FRA/2007/001

Content

1 Introduction

This guidance addresses rubber conversion and the related cleaning of equipment, presenting options to substitute or reduce the use of VOC and its resulting emissions.

Table 1: Scope definition of the VOC Solvent Emission Directive (SE Directive)

SE Directive – Scope definitions (Annex I)
The activity 'rubber conversion' is defined as 'any activity of mixing, milling, blending, calendering, extrusion and vulcanisation of natural or synthetic rubber and any ancillary operations for converting natural or synthetic rubber into a finished product'. The SE Directive covers installations in which this activity is taking place with an annual organic solvent consumption greater than 15 tonnes.

This guidance document does not cover the manufacture of paints or adhesives with rubber.

The SE Directive lays down the following activity specific emission limit values for rubber conversion:

THE SE DIRECTIVE APPLIES TO RUBBER CONVERSION ACTIVITIES IF A SOLVENT CONSUMPTION OF 15 TONNES PER YEAR IS EXCEEDED

Table 2: Emission limit values of the SE Directive

SE Directive - Emission limit values (ELVs) (Annex II A – activity No. 18)				
Activity	**Solvent consumption threshold [tonnes/year]**	**ELVs in waste gases [mg C/Nm³]**	**Fugitive emission values [% of solvent input]**	**Total ELVs [% of solvent input]**
Rubber conversion	>15	20*	25**	25
Special provisions * If techniques are used which allow reuse of recovered solvent, the emission limit value in waste gases shall be 150. **The fugitive emission value does not include solvent sold as part of products or preparations in a sealed container.				

Instead of complying with the above ELVs, operators may choose to use a reduction scheme, following the specifications of Annex II (B) of the SE Directive.

Specific requirements apply for VOCs classified as CMR substances[1] as well as for halogenated VOCs which are assigned the risk phrases R40 or R68[2]. There is a general obligation to replace CMR substances– as far as possible – by less harmful substances or preparations within the shortest possible time. In the case of a mass flow ≥10 g/h for VOC classified as CMR substances or ≥100 g/h for halogenated[3] VOC with R40/R68 the ELVs in waste gases are 2 and 20 mg/Nm³ respectively, and these also apply when a reduction scheme is being used.

National legislation may define lower thresholds for solvent consumption, stricter ELVs or additional requirements.

2 Summary of VOC substitution/reduction

PROCESS IMPROVEMENTS ARE MAJOR VOC-REDUCING MEASURES IN THE RUBBER INDUSTRY

In the rubber conversion industry solvents are mainly used as tackifying agents to stick together different types of layers of rubber or rubber coated components and as mould release agents. The substitution or reduction of the solvents as tackifiers is often associated with changes in the production process and compound formulation.

In the tyre industry the use of high tackiness rubber or thin layers of high tackiness rubber bands instead of solvent-based tackifiers during the assembly is a very effective substitution. The combination of production steps (e.g. co-extrusion) is also an effective measure to avoid additional tackifying agents. For the pre-vulcanisation treatment water-based mould release agents are available as VOC substitutes.

The combination of production steps (e.g. co-extrusion), production line re-design to speed-up the process avoiding loss of compound tackiness or other production process improvements are also very effective measures to reduce the usage of tackifying VOC based solutions.

In the general rubber good industry water-based mould release agents are commonly used as solvent-free alternatives. Changes in the production process (e.g. co-extrusion) are also effective measures to reduce VOC emissions.

In case no VOC-free or VOC-reduced products or systems are available abatement technologies like adsorption by activated carbon or the use of regenerative thermal oxidation are effective VOC emission reduction measures.

1 CMR substances-carcingenic (R45,R49), mutagenic (R46), or toxic to reproduction (R60,R61)
2 After the implementation of the SE Directive a revision of the R-phrase R40 took place. The original wording of R40 was: 'Possible risk of irreversible effects'. The new wording is: 'Limited evidence of a carcinogenic effect'. In the 'old' version mutagenity (cat 3) was included. This mutagenic effect is now covered separately under R68: 'Possible risk of irreversible effects'. This new risk phrase does not include carcinogenicity. The 'new' version of R40 is obviously less restrictive than the old version. Until the SE Directive is adapted to this change, a final decision on which version applies can only be given by the European Court
3 Halogenated organic solvents are hydrocarbons with one or more of the following halogens: fluorine, chlorine (e.g. trichloroethylene), bromine (e.g. n-propyl bromide) or iodine.

3 Description of the activity and related industry sectors

In Europe (EU 27), approximately 4200 companies produce rubber products. The total amount of transformed rubber in 2007 was 4 million tons (35% natural rubber, 65% synthetic rubber). [ETRMA 2008]

The rubber industry can be divided into two main groups of activities: tyre production and general rubber goods industry.

THE TYRE INDUSTRY IS THE MOST IMPORTANT USER OF RUBBER

Worldwide, around 70% of the natural rubber production is supplied to the tyre industry. In 2007, 88 tyre producing plants were operated in Europe. The annual tyre production in Europe[4] was 240 million units in 2006 (228 million units passenger car tyres and light vehicle tyres, 12 million medium & heavy commercial vehicle tyres) which is around 22 % of the worldwide tyre production.

The general rubber goods industry consists of more than 4100 companies, the majority being SMEs. It covers a wide range of products like medical, baby care, construction and automotive rubber goods. The automotive sector, with parts and components such as windscreen wipers, engine mountings, window seals, fan belts, etc., is the biggest consumer of rubber goods with 75% of the EU production [ETRMA 2008].

4 EU27+ Turkey

4 Technical process description

4.1 Process flow and relevant associated VOC emissions

General rubber goods production

The flow chart in Figure 1 gives an overview of the main process steps of the general rubber goods production applying solvent-based products and provides an overview of possible VOC emissions during the production process:

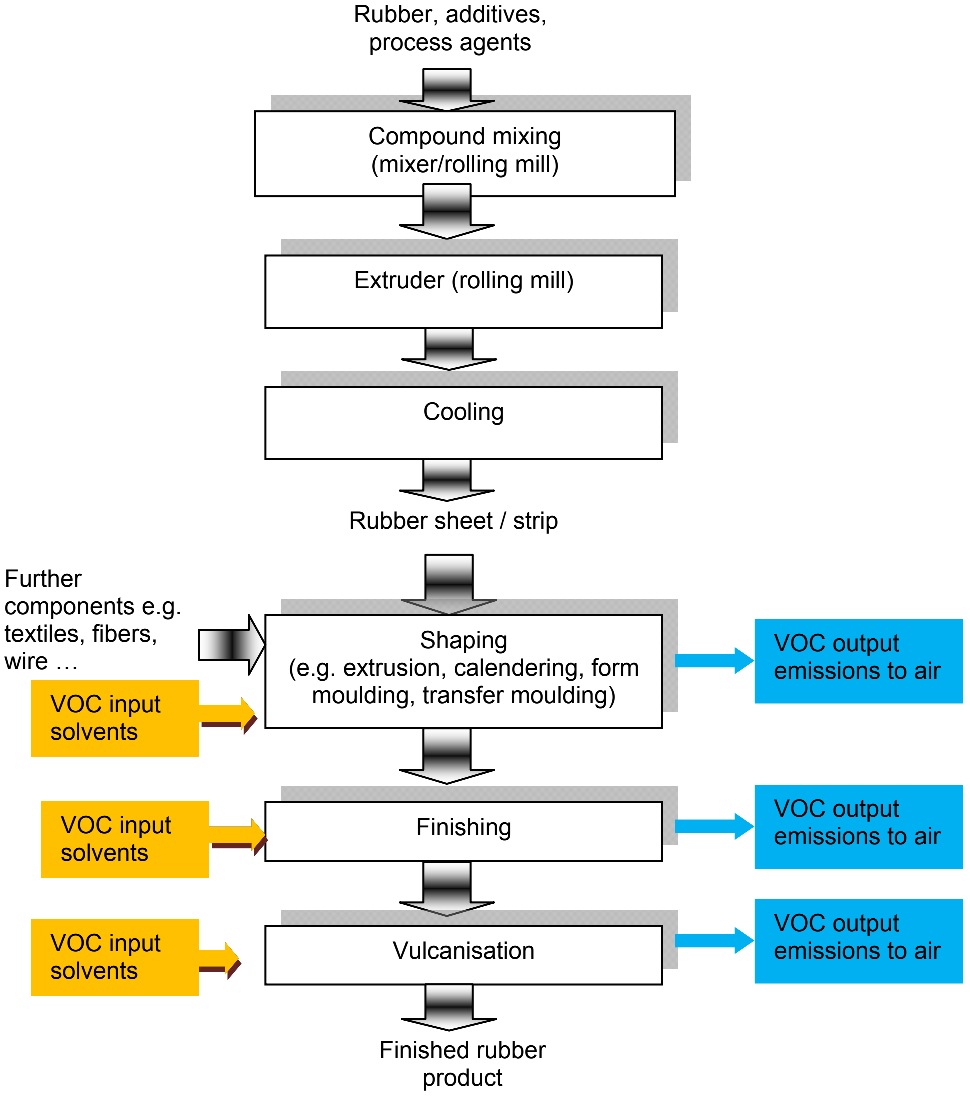

Figure 1: Possible VOC emission sources in general rubber goods production processes using solvent-based products

Tyre production

Figure 2 gives an overview of tyre production using solvent-based products and provides a summary of possible VOC emissions during the production process:

The compounding and mixing of the rubber sheet is analogous to the process described for the general rubber goods sector. In subsequent process steps like preparation of tyre components, assembly, finishing and before the vulcanisation process solvents are used.

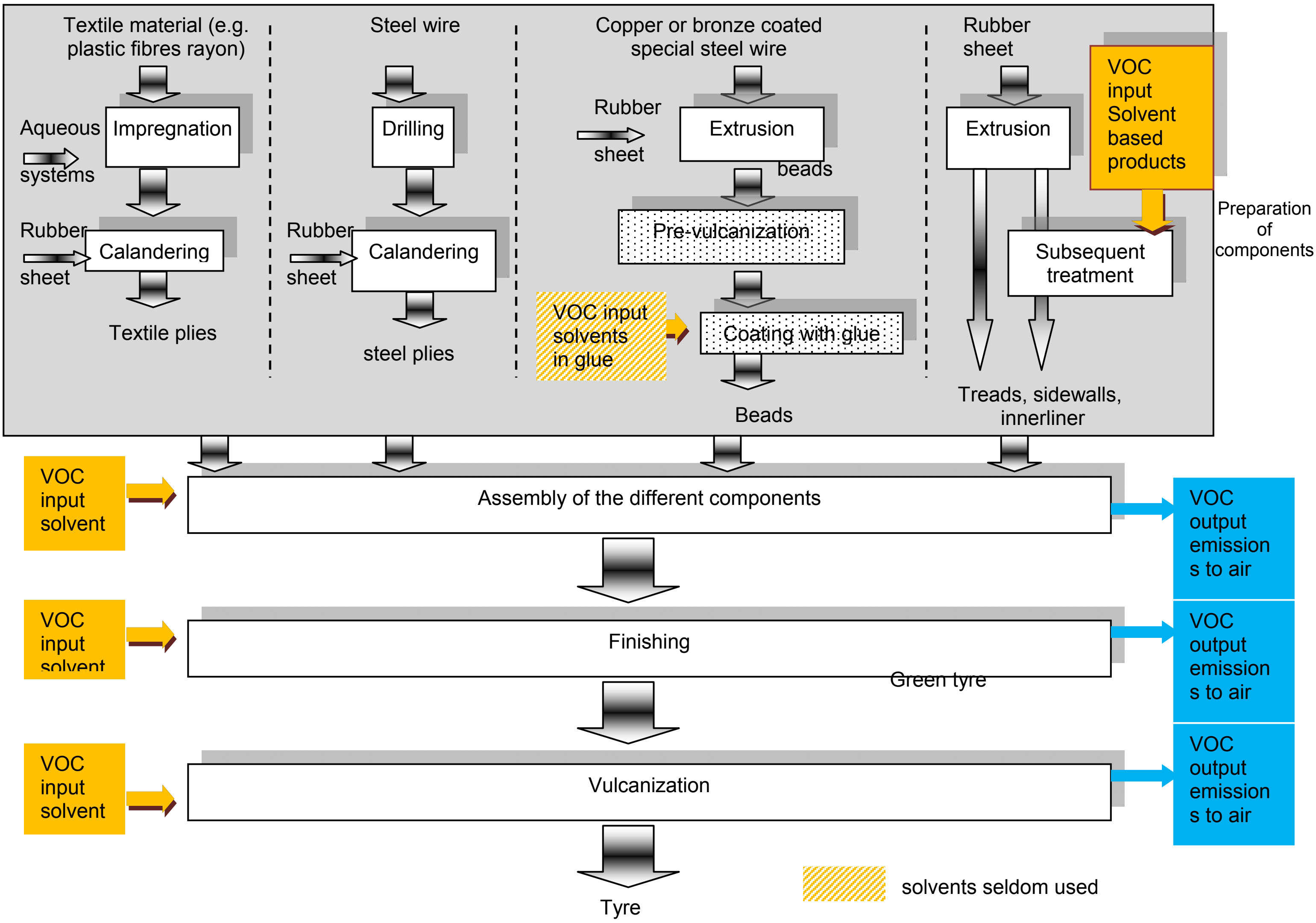

Figure 2: Possible VOC emission sources in tyre production processes using solvent-based products

The main function of the solvents in tyre production is the preparation of the uncured rubber surface before each production step. This is necessary to increase the adhesion by solvent to ensure different layers of compound are sticking together as needed (so called "refreshing" of rubber surfaces). Cleaning of compounds and of machinery in contact with rubber is also carried out using solvents, but is a less significant source of emissions, generally between 3 and 10% of solvent consumption.

The following table shows a typical breakdown of solvent emissions by process stage. This example is for a plant annually producing 46.500 tonnes of agricultural tyres with an input of 252.4 tonnes of solvents [SNCP 2002].

Table 3: Sources of VOC emission during the manufacture of agricultural tyres [SNCP 2002]

Process step	**Annual VOC emissions [t]**	**VOC emissions* [%]**
Preparation of beads	38.6	15
Preparation of treads (2 coatings)	68.4	27
Assembly of the tyre	41.5	17
Coating of the green tyre before vulcanisation	80.5	32
Reparation of tyres**	15	6
Cleaning activities	8.4	3
Total	**252.4**	**100**

* without any abatement technologies
**this production step is relevant after the vulcanisation process for tyres with minor defects

Car and truck and bus tyres production may have slightly different figures in terms of % of allocation of solvents in the production process (in general the tread preparation and extrusion may constitute the dominant factor). The total amount of VOC emissions depends on the dimension of the factory. A typical car tyre factory in the year 2000 was emitting from 400 to 800 tons of solvents per year.

4.2 Process description

General rubber good production

The general rubber goods sector covers a broad range of products with varying shapes, sizes and rubber-composition. As a consequence, different production steps may be necessary for different products. However, the following major process steps are essential for all rubber conversion processes:

- Compounding of rubber mixture
- Shaping
- Finishing

- Vulcanisation

For the compounding and mixing of rubber mixtures no solvents are used.

Preparation of components

Some products require the preparation of components e.g. fibres in the case of tubes or other re-enforced components. The preparation stage may involve the use of solvents.

For many products, a combination of rubber with metal (or another material such as a textile) is used. The metal typically has the function of stabilising or re-enforcing the product.

Shaping

Various techniques are used to shape the rubber mixture including extrusion, calendering, form moulding or transfer moulding.

Extrusion machines are typically used to form rubber into bars, tubes, profiles, or sheets or to encase cables and wires. Where extrusion is the only production process, the shaped rubber products subsequently pass directly to a drying oven for curing. Within the shaping process solvents are partly used.

Calenders are used to form thin sheets of rubber coated materials (e.g. fibres). For this type of production no organic solvents are in use.

Formed articles are produced by processes like pressing, transfer moulding and injection-moulding. These processes typically combine shaping and vulcanisation in one step. Solvents are used as mould release agents (see below vulcanisation).

Finishing

During this production step, the final product is built up from layers of extruded, calendered or re-enforcing materials (e.g. wire, aramid fibres, etc.).

Solvent based adhesives (“cement”) are used to stick together the different layers.

Vulcanisation / Curing

Vulcanisation changes the properties of the rubber from thermoplastic to elastic by cross-linking macromolecules of the rubber at elevated temperatures. No solvents are used for the vulcanisation process itself. But to increase the flow of the rubber mixture into the mould and to avoid sticking of the vulcanised product to the mould, solvent based mould release agents are often applied as pre-treatment before the vulcanisation.

Cleaning of equipment

Organic solvents are partly used for cleaning of equipment.

Tyre production

Tyre production consists of numerous process steps starting with the compounding of the rubber mixture, then the production of the component parts of the green tyre (e.g. textile cord, beads, treads), and finally the assembly and the vulcanisation of the green tyre. The different productions steps are illustrated in section 4.1.

Basically, a tyre consists of the following components:

- Inner rubber liner
- Belt of several layers of steel cord
- Two rings of steel bead wire coated in rubber
- Rubber side walls
- Various plies of re-enforcing fibres sandwiched in rubber
- A thick rubber tread

TYRES ARE BUILT UP BY SEVERAL DIFFERENT LAYERS OF RUBBER AND RUBBER COATED COMPONENTS

The manufacture of certain components of the tyre e.g. impregnated textile cord can take place either in the tyre production plant or at the plant where the textile is produced.

The main production steps are the following:

Mixing/Compounding

The compounding and preparation of the rubber mixture takes place in special mixers ("Banbury mixers"). After extrusion or calendering the final rubber compounds are ready for further application. This production step does not involve the use of solvents.

Preparation

This covers a number of different processes involving the preparation of the different components of the tyre like textile plies, steel belt, beads and treads. Extrusion of treads and other components in these steps are the processes mainly involved in the use of organic solvents in order to tackify the rubber.

Assembly

The individual components of the tyre are assembled during this phase and thus the tyre is built up layer by layer. Solvent-based products are used as “cement” (solvent with a small percentage of compound dissolved in) to adhere the different layers together. The main function of the cement is to prepare or to “refresh” the surface of the different layers, enhancing the tackiness of the different surfaces.

Finishing

After assembly of the components, forming/shaping of the tyre takes place during the finishing phase. During this production step solvents may be used as lubricants, for certain types of tyres. It does not represent a significant contribution to the total solvent consumption of the process.

Vulcanisation

During the vulcanisation process the rubber changes its properties from thermoplastic to elastic. In some cases the “green” tyre is treated with solvent-based mould release agents before the vulcanisation process. These enhance the flow properties of the green tyre into the mould.

Cleaning of equipment

Organic solvents are partly used for cleaning of equipment in contact with rubber.

5 Solvent use, emissions and environmental impact

5.1 Solvents used

General Rubber goods

In the general rubber goods industry the following solvents are commonly used as tackifiers and for cleaning activities.

Table 4: solvents used in the general rubber good manufacture [SNCP 2002]

solvent	Function
toluene	Adhesive
ethanol	Cleaning
trichloroethylene	Cleaning
Methyl ethyl ketone (Butanone)	Pre-treatment of components

Tyre industry

In the tyre industry, only heptane or light naphtha fractions are used as solvents in various process steps during manufacture. Heptane is the main component (90%) of the “cement” which is used for tackifying activities in the various assembly stages.

5.2 Solvent consumption and emission levels

The annual solvent consumption by the rubber industry is ~ 4% of total European solvent consumption [ESIG].

In the case of tyre manufacture the average emission factor has changed in the last 10 years from 7.1 kg/t of tyre to about or even less than 3 kg/t of tyre for certain types of tyres [SNCP 2002], [Bridgestone 2008A], [Michelin 2007], [Pirelli 2007]. In 2000, VOC emissions from tyre production were estimated to be 22 kt representing 0.21% of the total NMVOC emission in the EU 25 [EGTEI]. In general rubber goods manufacturing the average solvent emissions was reduced from 13.8 kg/t of product (1990) to 8 kg/t of product in 1999 [SNCP 2002]. At present average VOC emissions are below 5 kg/t of product.

THE VOC EMISSION FACTOR IN THE RUBBER INDUSTRY HAS DECREASED SIGNIFICANTLY IN THE LAST 10 YEARS

5.3 Key environmental and health issues

VOC emissions, together with NO_x emissions, are precursors of ground level ozone formation in the presence of sunlight. Existing occupational workplace limits should be taken into consideration.

Emissions of VOC to air may occur from:

- the storage of the solvents
- the preparation of components

- the assembly of components
- finishing
- vulcanisation
- cleaning operations.

Spills and leaks from storage areas may result in emissions to soil and groundwater.

The process generates waste containing solvents which need to be disposed in a way that emissions to air, soil and groundwater are prevented or limited.

In the general rubber good production the halogenated solvent trichloroethylene (R45, R68; R67; R36/38; R52/53) is of special concern.

6 VOC Substitution

The following sections describe potential substitutes for VOC (using VOC-free and VOC-reduced systems). There are also descriptions of the application technologies or special conditions needed and the advantages and disadvantages compared to systems that use solvents with a high VOC content.

6.1 VOC-free systems

This section describes the ways that VOC-free products or systems can be used to replace the organic solvents currently used.

6.1.1 Water-based systems

General: cleaning

Solvent based cleaning activities can be substituted in most cases by VOC-free products like water-based cleaners with the same cleaning properties.

Tyre production

WATER-BASED MOULD RELEASE AGENTS ARE REDUCE THE USE OF SOLVENTS SIGNIFICANTLY

Water-based systems are available and in use for the pre-vulcanisation treatment, which in conventional systems is a major source of VOC emission.

The use of these water-based mould release agents results in higher energy costs for the drying process. In addition the drying time is prolonged.

General rubber goods production

Water-based alternatives are available for injection, compression or transfer moulds [Henkel 2008].

6.1.2 Switch to VOC-free technology

Tyre production: Use of high tackiness rubber

THE USE OF AN ADHESIVE RUBBER BAND IN THE TYRE ASSEMBLY IS AN EFFECTIVE MEASURE TO REDUCE VOC EMISSIONS

The assembly of tyre components uses solvent based products as tackifying agents, but the same effect can be achieved using an adhesive rubber strip containing tackifying resins in the formulation and thus solvent based cements are not necessary later in the assembly process.

The use of high tackiness rubber or thin layers of high tackiness rubber bands might require both some modifications of the assembly process and high investment costs. In addition the adoption of the tackifying resins and the technical realisation of the reformulated rubber is very time and cost intensive.

Generally the improvement of tackiness performance of compounds is an effective measure to reduce VOC emissions for all extruded compounds.

Tyre-Production: Co-extrusion

Co-extrusion means that different layers or components which are foreseen to be stuck together during the assembling of the tyre are extruded in one production step. With this technology the use of tackifying agents - which are necessary to adhere the layers - can be avoided.

This technology requires high investment costs because the extrusion machines have to be adjusted – in the best case - or replaced by new ones.

For new lines of passenger tyres this technology is state of the art. In some cases solvent application might be still necessary but only to a very limited extent compared to conventional installations.

General rubber goods: Solvent free production of printing blankets

NEW TECHNOLOGY ALLOWS 100% VOC-FREE PRODUCTION OF PRINTING BLANKETS

Printing blankets typically consist of three different rubber layers. The production of printing blankets is conventionally carried out by solvent-intensive painting technology.

Since a few years a new production process is available. The roller-head-installation combined with a three-roll calender allows a 100% free production of printing blankets.

This new technology requires high investment costs.

[Contitech 2008], [KGK 2004]

6.2 VOC-reduced systems

If the complete substitution of organic solvents is impractical then changing to systems with a reduced VOC content, such as those described in this section, can decrease emissions.

Tackifying agents with reduced VOC-content or less volatile components are available, but the applicability of these products needs to be tested for each process. In the tyre industry cements are available with different solid content (e.g. 5, 8, 10, 15 or 20%).

7 Other VOC emission prevention measures and abatement techniques

Preventive measures, process improvements and abatement techniques can be used to reduce VOC emissions if VOC substitution as described in section 6 is not possible.

In the rubber industry process improvements play a very important role to reduce VOC emissions and the following measures are commonly applied.

7.1 Process improvements

7.1.1 Tyre production

a) Installation of new extrusion technology (see co-extrusion under section 6.1.2)

With the installation of new extrusion technologies the number of production process using VOC relevant rubber solutions can be reduced (e.g. the different production steps for components can be reduced by combining them in one step)

PROCESS IMPROVEMENTS OFTEN REQUIRE HIGH INVESTMENT COSTS

b) Installation of an assembly machine associated with the extruder

Directly after the extrusion process the rubber surface typically is warm and thus stickier. This tackiness steadily decreases over the course of time. When the extrusion process is associated directly with the assembly this process-related tackiness can be utilised to stick layers together. The use of tackifying agents can be significantly reduced.

c) Installation of a new system replacing the extrusion/coating of textile plies and other plies: this implies the full redesign of the process and therefore can only be applied to completely new installations and only for certain tyre types (passenger tyres)

d) Use of auto-spray systems for the spraying of the solvent-rubber solution (cement) on the extruded components instead of manual wiping of components

e) Installation of peristaltic pumps: accurate deposition of solvent-rubber solution over the extruder to minimize excess usage of solvents instead of hand brushing or dip tanks which often can lead to excessive application of solvent: the dissolution is applied drop by drop on treads

f) Use of closed tank systems like solvent boxes with plunger can instead of open boxes

The measures mentioned under points d) – f) are aiming to optimize the application of solvent/rubber solutions. Apart from the investment costs, these measures may also cause increased maintenance costs (e.g. blockage of the holes from which the rubber solution is applied on components, due to the rubber solids accumulation with time).

7.1.2 General rubber goods production

a) Installation of new extrusion technology (see section 6.1.2) co-extrusion)

b) Use of auto-spray systems instead of manual wiping of components

c) Use of closed solvent tank systems

7.2 Abatement technologies / End of pipe measures

Exhaust gases can be treated to reduce VOC emissions using either carbon filters to adsorb and then reuse VOCs or by thermal oxidation.

7.2.1 Activated carbon adsorption

Activated carbon is suitable for both halogenated and non-halogenated solvents. The recovery of the solvents can either take place on-site or externally. On-site recovery is of limited benefit to small companies as the carbon regeneration equipment is costly and experience is needed to use it properly. This is especially true for the systems for halogenated solvents.

Activated carbon adsorption is applicable for flow rates between 100 and 100,000 m³/h, with solvent concentrations of up to 50 g/m³. The recovery rate depends on, among other things, the type of activated carbon used and the operating conditions. Fresh activated carbon costs about 1 - 1.50 €/kg, while the cost for external recovery of the solvents is about 0.60 €/kg. [Donau Carbon 2008]

Compared with the investment costs for thermal oxidisers (about 150,000 €), those for activated carbon filters are significantly lower (20,000-30,000 €) but the operational costs (replacement of the activated carbon) are higher. [CTP 2008]

In the tyre manufacturing industry activated carbon is only used to a minor extent due to the high flow rates and high VOC concentrations typically occurring in this industry.

7.2.2 Thermal oxidation of solvent emissions

Thermal oxidation is only recommended for non-chlorinated solvents unless high temperature (> 1,100 °C) is used. Otherwise, there is a risk of generating chlorinated pollutants (e.g. dioxins).

Two types of thermal oxidiser are in use in the rubber industry, regenerative and recuperative. Both destroy VOCs by incineration (oxidation), but the systems differ in how waste heat is recovered.

Regenerative thermal oxidation has at least two heat exchangers, consisting of beds filled with material that will allow air to pass while serving as a mass to absorb and store heat. While one bed is heated by the exhaust gas from the burner another bed gives off its stored heat to the VOC laden incoming gas. In recuperative thermal oxidation the heat is transferred directly - via a heat exchanger - from the outgoing air stream to the incoming air stream.

Regenerative oxidation tends to be more efficient than recuperative thermal oxidation as it uses the recovered energy more efficiently to pre-heat incoming process air to oxidation temperatures (~ 800 °C), consequently its operating costs are significantly lower than for recuperative oxidation systems. Regenerative thermal oxidation systems are particularly effective for process streams with relatively low solvent loadings but their operating costs are highly dependent on the efficiency of the heat exchanger.

Regenerative thermal oxidation systems are widely used because they are relatively insensitive to the composition of the solvents in the process air and the concentration.

Recuperative systems are mainly used for small flow rates - at higher rates the systems are not cost effective. They are often used in combination with catalytic oxidation systems. Catalytic systems operate at much lower temperatures (350 – 500 °C) therefore the emission of NO_x is significant lower. Dust and catalyst poisons (e.g. sulphur-compounds) must be avoided.

THE AUTO-THERMIC POINT OF REGENERATIVE THERMAL OXIDATION IS ABOVE 2-3 G VOC/NM³

Natural gas is needed to heat up thermal oxidisers to an operating temperature of 800 °C (or 350-500 °C for catalytic systems) and the process is only autothermic when the VOC concentration of the waste gas is above 2-3 g VOC/Nm³ (for regenerative thermal oxidation). The resulting heat of the burning process, however, can be recovered and can be used for different purposes e.g. steam production.

7.3 Organisational measures

Significant reductions in VOC emissions may be achieved by organisational measures, such as avoidance of interim steps or long waiting times between production steps. Long waiting times between the different production steps require a refreshing of the surfaces as the stickiness of the rubber surface decreases after the production process by and by.

8 Summary of VOC emission reduction measures

Table 5 summarizes the various approaches to substitute or reduce VOC emissions as described in sections 6 and 7:

Table 5: Measures for VOC substitution and VOC reduction for rubber conversion

Objectives	**Description**	
	General rubber goods industry	**Tyre industry**
VOC-free Systems	- Use of water-based mould release agents - Use of water-based cleaning agents - New production technologies (e.g. for printing blankets)	- Use of water-based mould release agents - Use of water-based cleaning agents - Co-extrusion of components - Use of high tackiness rubber
VOC-reduced Systems	- Use of VOC reduced tackifying agents	- Use of VOC reduced tackifying agents
Process Improvements	- use of auto-spray systems instead of hand wiping of components - use of closed tank systems	- installation of an assembly machine associated with the extruder - installation of a new assembly system which replaces the extrusion/coating of the textile plies - use of auto-spray systems instead of hand wiping of components - installation of a dip tank on the extruder instead of hand brushing treads with solutions - use of closed tank systems
Abatement Technologies	- Use of activated carbon adsorption - Use of regenerative or recuperative thermal oxidation	- Use of activated carbon adsorption (only for small production units) - Use of regenerative or recuperative thermal oxidation

9 Good practice examples

9.1 Example 1: Tyre production

At a tyre production plant the major part of solvent input (95%) is in cement (tackifying agent) and the remaining 5% is used for cleaning or mold releasing.

Before making any changes, the average VOC emission was 10-11 kg/t of tyres. The following measures have since been introduced to reduce the VOC consumption and thus the emissions:

- Application of solvent-reduced or solvent-free tackifying agents
- Application of water-based mould release agents
- Installation of an improved extrusion method
- Reformulation of the products
- Installation of peristaltic pumps on the extruder instead of hand brushing or dip tanks
- Redesign of the process (avoidance of interim steps, speeding-up the production process to avoid refreshing of the rubber before next production step.
- Reallocation of process steps to minimize waiting time
- Use of closed tank systems

Major VOC emission reductions could be achieved by a reformulation of compounds, redesign of the process and a reallocation of the process steps. In addition, with these organisational measures the speed of the production line could be increased significantly.

After the implementation of all these measures, VOC emissions have been reduced up to 3 kg/t of tyres. No abatement technologies have been necessary to achieve these reductions.

9.2 Example 2: Tyre production

The company involved produces tyres for the agricultural sector (46,500 tonnes/year). The production steps comprise the mixing of rubber compounds, preparation of components, assembly/finishing and vulcanisation.

The company identified the activities shown in Table as VOC emission relevant:

Table 6: Overview of possible reduction measures and corresponding VOC emission reductions and costs

Description of the technology	Annual reduction of solvent consumption	Costs (constant production) [€]
Reduction of the solvent use during the extrusion of the beads	-7.92%	0
Elimination of the first coating step for the treads	-13.55%	-15,000
Installation of new equipment for the assembly	-7.92%	5,000,000
Substitution of solvent based solution for the repair of agricultural tyres by water-based products	-5.94%	2,000
Installation of equipment for the production of contact rubber for the treads on the extrusion line	-6.73%	300,000
Elimination of solvent based cleaning agents	-1.35%	-1,500
Replacement of solvent based products for the treatment of the tyres before vulcanisation by water-based systems	-2.18%	2,500
Replacement of the solvent based products used during the assembly of the tyres following process modifications	-15.85%	43,000
Total	**-61.45 %**	**5,326,000**

Apart from the significant VOC reduction also the productivity of the plant will increase with the implementation of the above described measures and new technologies. But the return of investment will be several years due to the high initial investment costs of certain measures.

10 Emerging techniques and substitutes under development

No emerging techniques have been reported.

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